(19) Canadian Intellectual Property Office | Office de la Propri,t, Intellectuelle du Canada

An Agency of Industry Canada | Un organisme d'Industrie Canada

(11) CA 2 300 719 (13) A1

(40) 15.09.2001
(43) 15.09.2001

(12)

(21) 2 300 719

(51) Int. Cl.7: C02F 3/30

(22) 15.03.2000

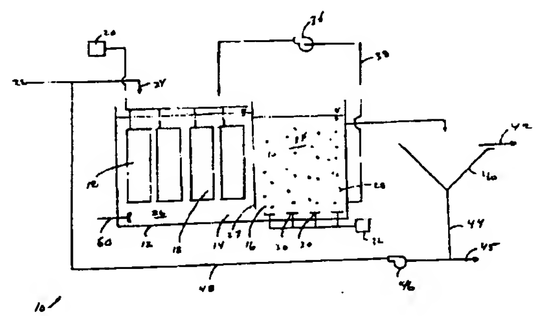
(71)
ZENON ENVIRONMENTAL INC.,
845 HARRINGTON
COURT , BURLINGTON, O1 (CA).

(72)
PHAGOO, DEONARINE (CA).
HUSAIN, HIDAYAT (CA).
COTE, PIERRE (CA).

(74)
BERESKIN & PARR

(54) PROCESSUS AU COURS DUQUEL LE FILM BIOLOGIQUE UTILISE S'APPUIE SUR UNE MEMBRANE
(54) MEMBRANE SUPPORTED BIOFILM PROCESS

(57)
A first reactor for treating wastewater has an anaerobic section, a plurality of gas transfer membrane modules, and an aerobic section. A biofilm is cultivated on the surface of the gas transfer membranes, the biofilm having aerobic and anoxic zones and being in fluid communication with the anaerobic section. The aerobic section is also in fluid communication with the anaerobic section. Wastewater flows through the reactor so as to be treated in the anaerobic section, the aerobic section and by contact with the biofilm. Treated wastewater leaves the reactor from the aerobic section flowing first through a liquid-solid separation device such as a clarifier. The supernatant from the clarifier is connected to the outlet and a portion of a settled sludge at the bottom of the clarifier is recycled to the reactor. Biological reduction of COD, BOD, nitrogen and phosphorous are achieved. In a second reactor, phosphorous is also removed chemically in a precipitation branch in fluid communication with the top of the anaerobic section which is at least periodically quiescent such that the mixed liquor may at least partially settle.



BEST AVAILABLE COPY

Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2300719 A1 2001/09/15

(21) 2 300 719

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(22) Date de dépôt/Filing Date: 2000/03/15

(41) Mise à la disp. pub./Open to Public Insp.: 2001/09/15

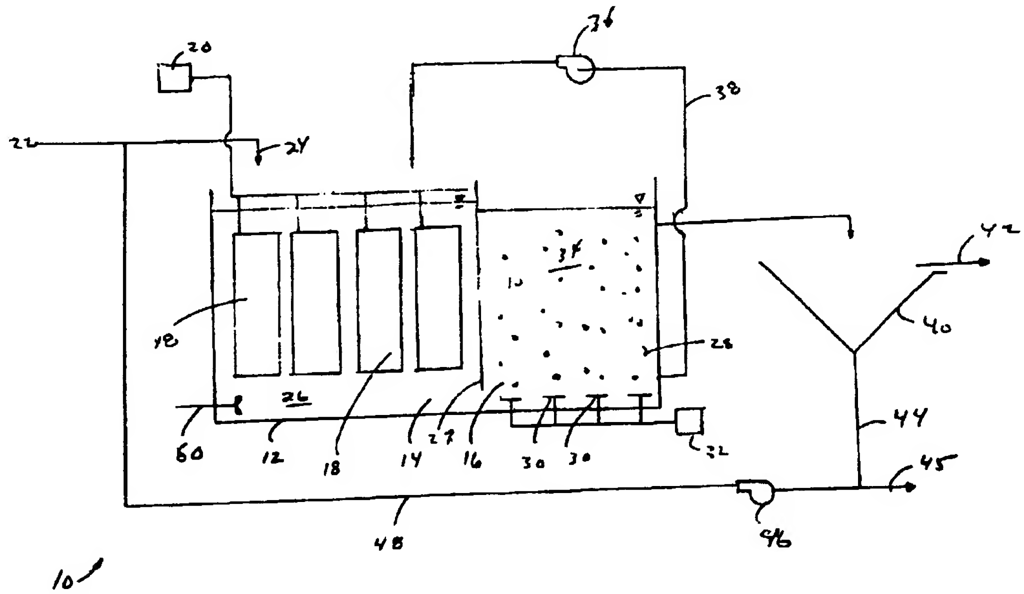
(51) Cl.Int.[7]/Int.Cl.[7] C02F 3/30

(71) Demandeur/Applicant:
ZENON ENVIRONMENTAL INC., CA

(72) Inventeurs/Inventors:
COTE, PIERRE, CA;
HUSAIN, HIDAYAT, CA;
PHAGOO, DEONARINE, CA

(74) Agent: BERESKIN & PARR

(54) Titre : PROCESSUS AU COURS DUQUEL LE FILM BIOLOGIQUE UTILISE S'APPUIE SUR UNE MEMBRANE
(54) Title: MEMBRANE SUPPORTED BIOFILM PROCESS



(57) Abrégé/Abstract:
A first reactor for treating wastewater has an anaerobic section, a plurality of gas transfer membrane modules, and an aerobic section. A biofilm is cultivated on the surface of the gas transfer membranes, the biofilm having aerobic and anoxic zones and being in fluid communication with the anaerobic section. The aerobic section is also in fluid communication with the anaerobic section. Wastewater flows through the reactor so as to be treated in the anaerobic section, the aerobic section and by contact with the biofilm. Treated wastewater leaves the reactor from the aerobic section flowing first through a liquid-solid separation device such as a clarifier. The supernatant from the clarifier is connected to the outlet and a portion of a settled sludge at the bottom of the clarifier is recycled to the reactor. Biological reduction of COD, BOD, nitrogen and phosphorous are achieved. In a second reactor, phosphorous is also removed chemically in a precipitation branch in fluid communication with the top of the anaerobic section which is at least periodically quiescent such that the mixed liquor may at least partially settle.

ABSTRACT

A first reactor for treating wastewater has an anaerobic section, a plurality of gas transfer membrane modules, and an aerobic section. A biofilm is cultivated on the surface of the gas transfer membranes, the biofilm having aerobic and anoxic zones and being in fluid communication with the anaerobic section. The aerobic section is also in fluid communication with the anaerobic section. Wastewater flows through the reactor so as to be treated in the anaerobic section, the aerobic section and by contact with the biofilm. Treated wastewater leaves the reactor from the aerobic section flowing first through a liquid-solid separation device such as a clarifier. The supernatant from the clarifier is connected to the outlet and a portion of a settled sludge at the bottom of the clarifier is recycled to the reactor. Biological reduction of COD, BOD, nitrogen and phosphorous are achieved. In a second reactor, phosphorous is also removed chemically in a precipitation branch in fluid communication with the top of the anaerobic section which is at least periodically quiescent such that the mixed liquor may at least partially settle.

TITLE: MEMBRANE SUPPORTED BIOFILM PROCESS

FIELD OF THE INVENTION

This invention relates to a process for treating wastewater to remove one or more of nitrogen, phosphorous, BOD and COD.

BACKGROUND OF THE INVENTION

Discharging wastewater containing large amounts of carbon (BOD or COD), nitrogen and phosphorous into a natural body of water causes eutrophication, algae blooms, pollution and health problems. Various processes have been developed to treat wastewater to remove some or all of the carbon, nitrogen and phosphorous, some of which will be summarized below.

Activated Sludge with Chemical Phosphorous Removal

In a typical activated sludge process, wastewater flows in series through an anoxic reactor, an aerobic reactor and a clarifier. Effluent from the clarifier is released to the environment. Activated sludge from the bottom of the clarifier is partially recycled to the anoxic reactor and partially wasted. Significant removal of nitrogen requires a significant rate of recycle to alternately nitrify and denitrify the wastewater.

Phosphorous is removed by dosing soluble metal salts, such as ferric chloride or aluminum sulphate, at one or more points in the process into the aerobic reactor to precipitate phosphate metal salts. The waste water, however, contains many different ions which create undesirable side reactions. As a result, and particularly where very low

effluent total phosphorus levels are required, precipitating phosphorous may require the addition of 2-6 times the stoichiometric amount of the metal salt. Accordingly, these processes result in high chemical costs, high sludge production, and a high level of metallic impurities in the sludge.

Activated Sludge with Biological Phosphorous Removal

Activated sludge techniques can also be modified to use microorganisms to store the phosphates. For example, US Patent No. 4,867,883 discusses a process which attempts to encourage the selection and growth of Bio-P organisms which uptake phosphorus in excess of the amount normally needed for cell growth. Generally, the process consists of an anaerobic zone, an anoxic zone, an aerobic zone, and a clarifier. In the anaerobic zone, soluble BOD is assimilated and stored by the Bio-P organisms and phosphorus is released. Subsequently, in the anoxic and aerobic zones, the stored BOD is depleted and soluble phosphorous is taken-up in excess and stored as polyphosphates by the Bio-P organisms. In the clarifier, sludge containing phosphates settles out of the effluent. There is a denitrified recycle from the anoxic zone to the anaerobic zone, a nitrified recycle from the aerobic zone to the anoxic zone, and an activated sludge recycle from the clarifier to the anoxic zone. The sludge recycle is done in multiple phases to ensure that nitrates are not recycled to the anaerobic zone, which would limit phosphorous release. The biological mechanism by which bacteria release phosphorous in the anaerobic section involves the uptake of easily assimilated organic compounds such as volatile fatty acids (VFA). Depending on the level of VFA in the raw wastewater, an extra anaerobic section may be added at the head of the process.

One problem with this process is that the settling characteristics of the sludge in the clarifier impose significant design limitations. For example, the process cannot operate at very high process

solids levels or high sludge retention times, particularly when high removal rates of both nitrogen and phosphorous are required. As a result, the system is generally considered to be inefficient and there is a high generation rate of waste sludge. In some cases, sand filters are added to the tail of the process to help remove solids carryover from an overloaded clarifier and reduce the amount of phosphorous in the effluent.

Another problem with this process is that there is a build-up of phosphates in the system. The waste activated sludge contains Bio-P organisms rich in phosphorous. When the organisms in the waste activated sludge are digested, they release phosphorus which is typically returned back to the process in the form of digester supernatant. Consequently, this reduces the efficiency of phosphorus removal in the process and results in higher levels of phosphorus in the effluent. A partial solution to this problem is to employ a side stream process called 'Phos-Pho Strip' as described in US Patent No. 3,654,147. In this process, activated sludge passes from the clarifier to a phosphorus stripper. In the stripper, phosphorus is released into the filtrate stream by either: creating anaerobic conditions; adjusting the pH; or extended aeration. The resulting phosphate-rich filtrate stream passes to a chemical precipitator. The phosphate-free effluent stream is added to the main effluent stream, the waste stream from the precipitator containing the phosphates is discarded, and the phosphate-depleted activated sludge is returned to the main process.

Membrane Bioreactor with Chemical Precipitation

A membrane bioreactor can be combined with chemical precipitation techniques. In a simple example, precipitating chemicals are added to an aerobic tank containing or connected to a membrane filter. As above, however, dosages of precipitating chemicals substantially in excess of the stoichiometric amount of phosphates are required to

achieve low levels of phosphates in the effluent. This results in excessive sludge generation and the presence of metallic precipitates which increase the rate of membrane fouling or force the operator to operate the system at an inefficient low sludge retention time.

Membrane Supported Biofilm

U.S. Patent No. 4,181,604 describes a module having several loops of hollow fibre membranes connected at both ends to a pipe at the bottom of a tank containing wastewater. The pipe carries a gas containing oxygen to the lumens of the membranes through which the gas is supplied to the wastewater and to an aerobic biofilm growing on the outer surface of the membranes. In U.S. Patent No. 4,746,435, the same apparatus is used but the amount of oxygen containing gas supplied is controlled to produce a biofilm having aerobic zones and anaerobic zones and 1 to 7 ppm of oxygen in the waste water. This process provides simultaneous nitrification and denitrification without sludge recirculation but no phosphorous removal.

U.S. Patent No. 5,116,506 describes a reactor having an oxygen containing gas permeable membrane separating a reactor into a liquid compartment and a gas compartment. The liquid compartment contains wastewater. The gas compartment is provided with oxygen which diffuses through the membrane to support a biofilm layer. The biofilm layer has two parts, an aerobic layer adjacent the membrane and an anaerobic layer adjacent the wastewater. This process also provides simultaneous nitrification and denitrification but again no phosphorous removal.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a process for treating wastewater to produce an effluent with reduced

concentrations of one or more of nitrogen, phosphorous and carbon (BOD or COD).

In one aspect, the invention provides a hybrid wastewater treatment reactor combining a membrane supported biofilm and suspended growth biomass. The reactor has a first section containing a plurality of gas transfer membrane modules connected to an oxygen source and a second section having an oxygen source operable to create aerobic conditions in the second section. In the first section, the supply of oxygen to the membrane modules is controlled to cultivate a biofilm on the surface of the membranes having aerobic and anoxic zones and to facilitate cultivation of an anaerobic mixed liquor in the first section generally. In the second section, the diffusers and oxygen source facilitate cultivation of an aerobic mixed liquor. Wastewater enters the reactor through an inlet to the first section and flows through the reactor so as to be treated in the anaerobic section, in the aerobic section and by contact with the biofilm before leaving the reactor through a solid/liquid separator downstream of the second section. A portion of the settled sludge at the bottom of the clarifier is recycled to the first section.

Biological digestion of BOD, COD, nitrogen and phosphorous are achieved as summarized below:

- Rough removal of BOD or COD and nitrogen occur in the biofilm.
- Polishing denitrification and sludge reduction occur in the anaerobic mixed liquor.
- Volatile fatty acids (VFA) are assimilated and phosphorous is released in the anaerobic mixed liquor.
- polishing COD and BOD removal, polishing nitrification and biological phosphorous uptake occur in the aerobic mixed liquor.
- phosphorous is extracted as excess biomass by wasting a portion of the sludge settled in the clarifier.

In another aspect, the invention provides a modified reactor in which phosphorous is also extracted as a chemical precipitate. The anaerobic mixed liquor is most often quiescent allowing partial sedimentation of the anaerobic mixed liquor which produces a phosphorous rich solution near its surface. Alternatively, a portion of the anaerobic mixed liquor is treated in a solid-liquid separation device to produce a phosphorous rich solution. The phosphorous rich solution is treated in a precipitation branch having a source of phosphorous precipitating agents such as metal salts and a precipitate separation device such as a clarifier or hydrocyclone.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the present invention will now be described with reference to the following figures.

Figure 1 is a schematic representation of a reactor.

Figure 2 is a schematic representation of a second reactor.

DETAILED DESCRIPTION OF EMBODIMENTS

Hybrid Membrane Supported Biofilm Process with Biological Phosphorous Removal

Figure 1 shows a reactor 10 for treating wastewater having a tank 12 divided into first and second biological reaction sections which will be referred to as a membrane supported biofilm (MSB) section 14 and an aerated section 16 respectively. The two sections 14, 16 may be provided in a single tank 12 or in multiple tanks.

The MSB section 14 has one or more gas transfer membrane modules 18 connected to an oxygen supply 20. The oxygen supply 20 is typically a pump drawing air from the atmosphere or a source of oxygen or oxygen enriched air. The oxygen supply 20 supplies an oxygen containing gas to the membrane modules 18 at a pressure which causes oxygen to flow through the membrane modules 18. Oxygen flows through the membrane modules 18 by diffusion without creating bubbles. Suitable designs for such membrane modules 18 are known in the art. Examples are described in U.S. Patent No. 5,116,506 and in a co-pending application by the first named inventor of the present invention and others. The membrane modules 18 occupy between 2% and 20% of the volume of the MSB section 14. The remainder of the MSB section 14 is occupied by anaerobic mixed liquor 26 in an anaerobic part of the MSB section 14 in fluid communication with the outside of the membrane modules 18.

Screened wastewater 22 to be treated flows through an inlet 24 into the MSB section 14 wherein it becomes part of the anaerobic mixed liquor 26. Nutrients in the anaerobic mixed liquor 26 in combination with oxygen flowing through the membrane modules 18 cultivates a biofilm on the surface of the membrane modules 18. The oxygen supply 20 is controlled to provide sufficient oxygen to maintain an aerobic zone within the biofilm, preferably directly adjacent to the membrane modules 18. The oxygen supply is not sufficient, however, to create an entirely aerobic biofilm. Anoxic and possible anaerobic zones are also present in the biofilm, preferably in layers - the anoxic zone in a layer adjacent to the aerobic layer and the anaerobic zone, if any, adjacent to the anoxic zone. The oxygen supply is also not sufficient to oxygenate the anaerobic mixed liquor 26 which is in an anaerobic state at least in a region around the membrane modules 18. The anaerobic mixed liquor 26 is periodically agitated by operating a mechanical mixer 60, pumping through local recirculation loops or coarse bubble aeration (designed to not transfer significant amounts of oxygen to the anaerobic mixed liquor

26) to prevent complete settling of the anaerobic mixed liquor 26 and to control the thickness of the biofilm attached to the membrane modules 18.

Anaerobic mixed liquor 26 flows through a passage in a partition 27 to the aerated section 16 which is primarily an aerobic section. Bubbles 28 of oxygen containing gas are introduced into the aerated section 16 by diffusers 30 driven by a second oxygen supply 32, typically an air blower. The bubbles 28 are preferably fine and transfer oxygen to the anaerobic mixed liquor 26 making it a generally aerobic mixed liquor 34. Alternatively, other suitable aeration devices or oxygen sources operable to create aerobic conditions may be used in the second section.

A portion of the aerobic mixed liquor 34 is recycled to the MSB section 14 by a pump 36 in a second passage or recycle loop 38. Anoxic conditions are created in a localized zone in the MSB section 14 where the recycled aerobic mixed liquor 34 first mixes with the anaerobic mixed liquor 26. Another portion of the aerobic mixed liquor 34 flows to a clarifier 40 (or another liquid-solid separation device such as a membrane filter) and is separated into treated effluent 42 and settled activated sludge 44. Part of the sludge 44 is recycled to the MSB section 14 by a pump 46 in a recycle loop 48. Another part of the sludge 44 is discarded or treated further as waste activated sludge 45. The clarifier 40 and sludge recycle loop 48 may be sized smaller than a clarifier in conventional activated sludge systems to account for the portion of the total biomass that is attached as a film to the membrane modules 18. Similarly, the recycle loop 38 may be sized smaller than the aerobic to anoxic recycle in a conventional activated sludge process for biological nutrient removal because significant amounts of nitrification and denitrification occur in the biofilm attached to the membrane modules 18.

The MSB section 14 is a complex reactor comprising a plurality of reaction zones. An aerobic reaction zone or section (usually signalled by the presence of dissolved oxygen) exists in the biofilm layer on the membrane modules. Anoxic zones or sections (usually signalled by the presence of NO_3 but absence of dissolved oxygen) exist in the biofilm layer and in the anaerobic mixed liquor 26 where the recycled aerobic mixed liquor 34 enters the MSB section 14. An anaerobic zone or section (usually signalled by the absence of NO_3 and dissolved oxygen) exists in the anaerobic mixed liquor 26 generally. This collection of reaction zones allows the following processes to occur in the MSB section 14:

- Rough removal of BOD or COD occurs in the biofilm.
- Rough removal of nitrogen occurs in the biofilm, by means of alternate nitrification and denitrification in the aerobic and anoxic sections of the biofilm.
- Polishing denitrification occurs in the anaerobic mixed liquor 26.
- Volatile fatty acids (VFA) are produced by fermentation in the anaerobic mixed liquor 26.
- Phosphorous is released and VFA are assimilated by Bio-P organisms in the anaerobic mixed liquor 26.
- Sludge is reduced anaerobically in the anaerobic mixed liquor 26.
- Partial sedimentation of the anaerobic mixed liquor 26 produces a phosphorous rich solution near the surface of the aerobic mixed liquor 26.

The bubble-aerated section 16 is a simpler reactor, but still provides multiple functions including polishing COD and BOD removal, polishing nitrification and biological phosphorous uptake. These processes complement those occurring in the MSB section 14. For example, cycling mixed liquor between anaerobic and aerobic states

promotes sludge reduction through digestion. The uptaken phosphorous is removed with the waste activated sludge 45. The effluent 42 leaving the clarifier 40 thus has reduced levels of all of COD, BOD, nitrogen and phosphorous.

Hybrid Membrane Supported Biofilm Process with Chemical Phosphorous Removal

Figure 2 shows a second reactor 110 similar in structure and function to the reactor 10. In the second reactor 110, however, a chemical precipitation branch 50 is provided which receives fluid from the anaerobic mixed liquor 26, preferably from the top of the MSB section 14. The inlet to the chemical precipitation branch 50 is located away from the inlet 24 and the outlet from the recycle loop 38 so that the chemical precipitation branch 50 recieves liquid from a truly anaerobic portion of the anaerobic mixed liquor 26. Further, the anaerobic mixed liquor 26 is not agitated, except periodically to remove biofilm from the membrane modules 18, and thus the anaerobic mixed liquor 26 partially settles. The liquid near the top of the MSB section 14 is thus reduced in suspended biomass as well as being rich in dissolved phosphorous released by suspended organisms moving from an aerobic environment (in the aerated section 16) to an anaerobic environment. Alternatively, a solids lean liquid can be extracted from the MSB section 14 through a clarifier, membrane or other solids liquid separation device which, although requiring additional equipment, does not require settling in the MSB section 14 and so the mixer 60 may be operated continuously. Solids rich liquid from such liquid separation devices is returned to the reactor 10, preferably to the aerated section 16.

The liquid near the top of the MSB section 14 flows into a precipitation line 54, typically by gravity although a pump may also be used. Metal salts 56 are added to the precipitation line 54 to create either an amorphous sludge or a crystalline material that is removed in a

clarifier 58 or other precipitate separation process such as a hydrocyclone. Because of the reduced amount of suspended biomass in the liquid extracted from the MSB section 14, and the higher concentration of phosphorous relative to conventional activated sludge systems with chemical phosphorpous removal, phosphorous can be precipitated with more nearly stoichiometric doses of the metal salts. The resulting effluent may be either discharged or recycled to the reactor 10, preferably to the aerated section 16, and the resulting sludge or crystalline material may be either discarded or processed further.

Removing phosphorous in the chemical precipitation branch 50 reduces the concentration of phosphorous in the waste activated sludge 45. This reduces the risk that phosphorous will be release through sludge processing and recycled to the reactor 110. Having segregated a lower volume chemical sludge, its phosphorous content can be dealt with more easily.

Embodiments similar to those described above can be made in many alternate configurations and operated according to many alternate methods within the teachings of the invention, the scope of which is defined in the following claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A reactor for treating wastewater to reduce concentrations of one or more of BOD, COD, nitrogen and phosphorous comprising,

(a) an anaerobic section;

(b) a plurality of gas transfer membrane modules for supporting and oxygenating a biofilm on the surface of the gas transfer membranes, the biofilm being in fluid communication with the anaerobic section and having aerobic and anoxic zones; and,

(c) an aerobic section in fluid communication with the anaerobic section;

(d) a wastewater inlet; and,

(e) an outlet

wherein wastewater enters the reactor through the inlet and flows through the reactor so as to be treated in the anaerobic section, the aerobic section and by contact with the biofilm before leaving the reactor through the outlet.

2. The reactor of claim 1 further comprising a liquid-solid separation device between the aerobic section and the outlet.

3. The reactor of claim 2 wherein liquid separated in the liquid-solid separation device flows to the outlet and a portion of a sludge containing solids separated in the liquid-solid separation device is recycled to the reactor.

4. The reactor of claim 1 wherein the gas transfer membrane modules are located within the anaerobic section.

5. The reactor of claim 1 further comprising a precipitation branch having a source of phosphorous precipitating agents and a

precipitate separation device, the precipitation branch receiving fluid from the anaerobic section.

6. The reactor of claim 5 wherein the precipitation branch receives fluid from the top of the anaerobic section and the anaerobic section is quiescent from time to time such that the mixed liquor may at least partially settle.

7. A reactor for treating wastewater to reduce concentrations of one or more of BOD, COD, nitrogen and phosphorous comprising,

(a) a first section containing a plurality of gas transfer membrane modules connected to an oxygen source operable to cultivate a biofilm on the surface of the gas transfer membranes having aerobic and anoxic zones while not disturbing an anaerobic condition existing in the first section generally,

(b) a second section having an oxygen source operable to create aerobic conditions in the second section;

(d) a wastewater inlet to the first section;

(e) an outlet from the second section; and,

(f) a passage from the first section to the second section and a second passage from the second section to the first section,

wherein wastewater enters the reactor through the inlet and flows through the reactor so as to be treated in the anaerobic section, the aerobic section and by contact with the biofilm before leaving the reactor through the outlet.

8. The reactor of claim 7 further comprising a liquid-solid separation device between the second section and the outlet.

9. The reactor of claim 8 wherein liquid separated in the liquid-solid separation device flows to the outlet and a portion of a sludge

containing solids separated in the liquid-solid separation device is recycled to the reactor.

10. The reactor of claim 7 further comprising a precipitation branch having a source of phosphorous precipitating agents and a precipitate separation device, the precipitation branch being configured to receive fluid from the anaerobic section.

11. The reactor of claim 10 wherein the precipitation branch is configured to receive fluid from the top of the anaerobic section and the anaerobic section is quiescent from time to time such that the mixed liquor may at least partially settle.

12. A process for treating wastewater to reduce concentrations of one or more of BOD, COD, nitrogen and phosphorous comprising the steps of,

(a) treating the wastewater through anaerobic digestion;

(b) contacting the wastewater while it is generally in an anaerobic state with a biofilm having aerobic and anoxic zones; and,

(c) treating the wastewater through aerobic digestion.

13. The process of claim 12 further comprising the step of separating suspended solids from the wastewater.

14. The process of claim 13 wherein a portion of the suspended solids separated from the wastewater are recycled to the reactor.

15. The process of claim 12 wherein the steps of treating the wastewater through anaerobic digestion and contacting the wastewater while it is generally in an anaerobic state with a biofilm having aerobic and anoxic zones are performed simultaneously.

16. The process of claim 12 further comprising the steps of

(a) allowing the wastewater being treated by anaerobic digestion to settle at least periodically;

(b) withdrawing solids lean wastewater from the wastewater being treated by anaerobic digestion;

(c) precipitating compounds of phosphorous from the solids lean wastewater.

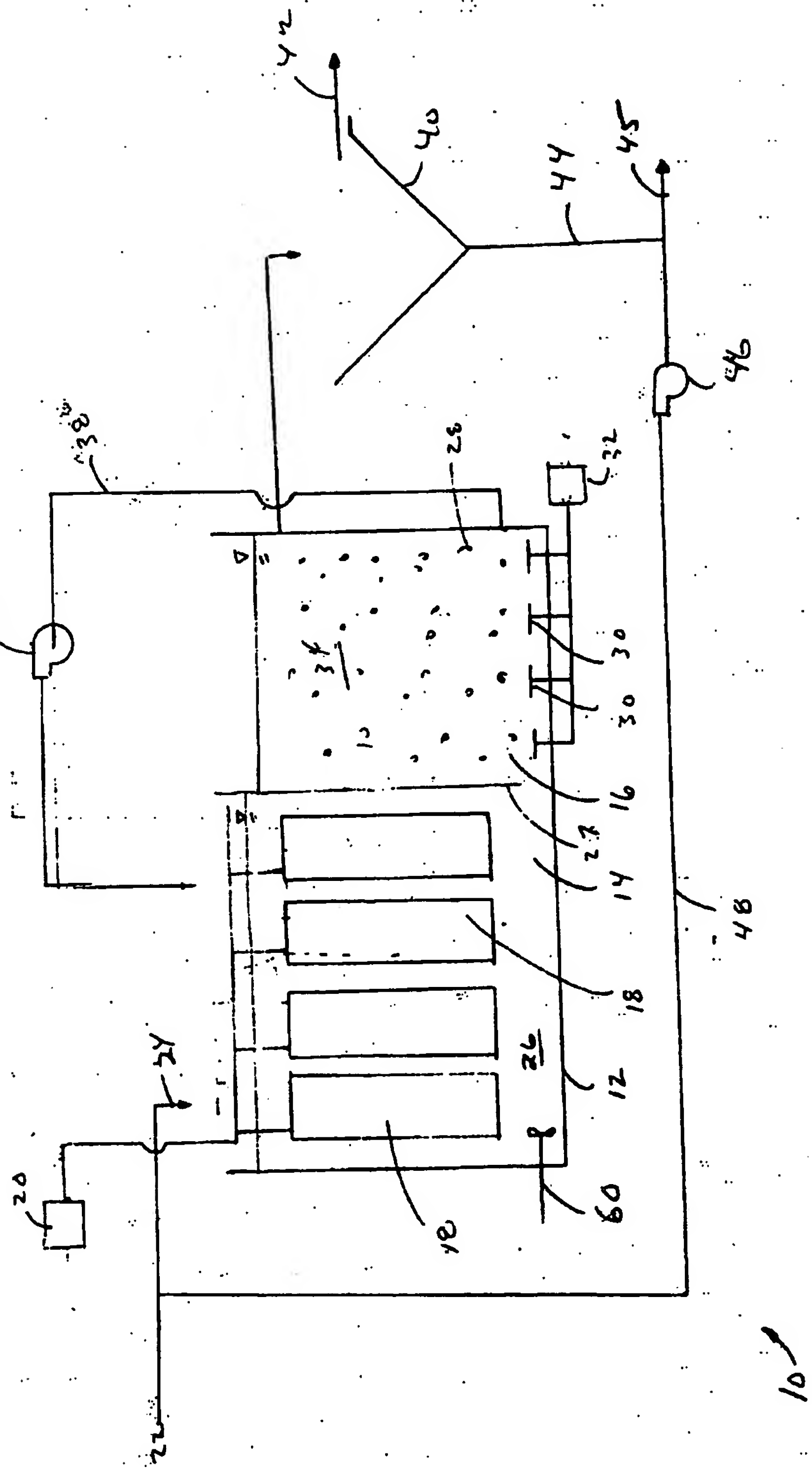

42
40
44
45
46
38
36
28
22
34
30
30
16
27
14
48
18
26
12
24
20
60
18
22
10

FIGURE 1

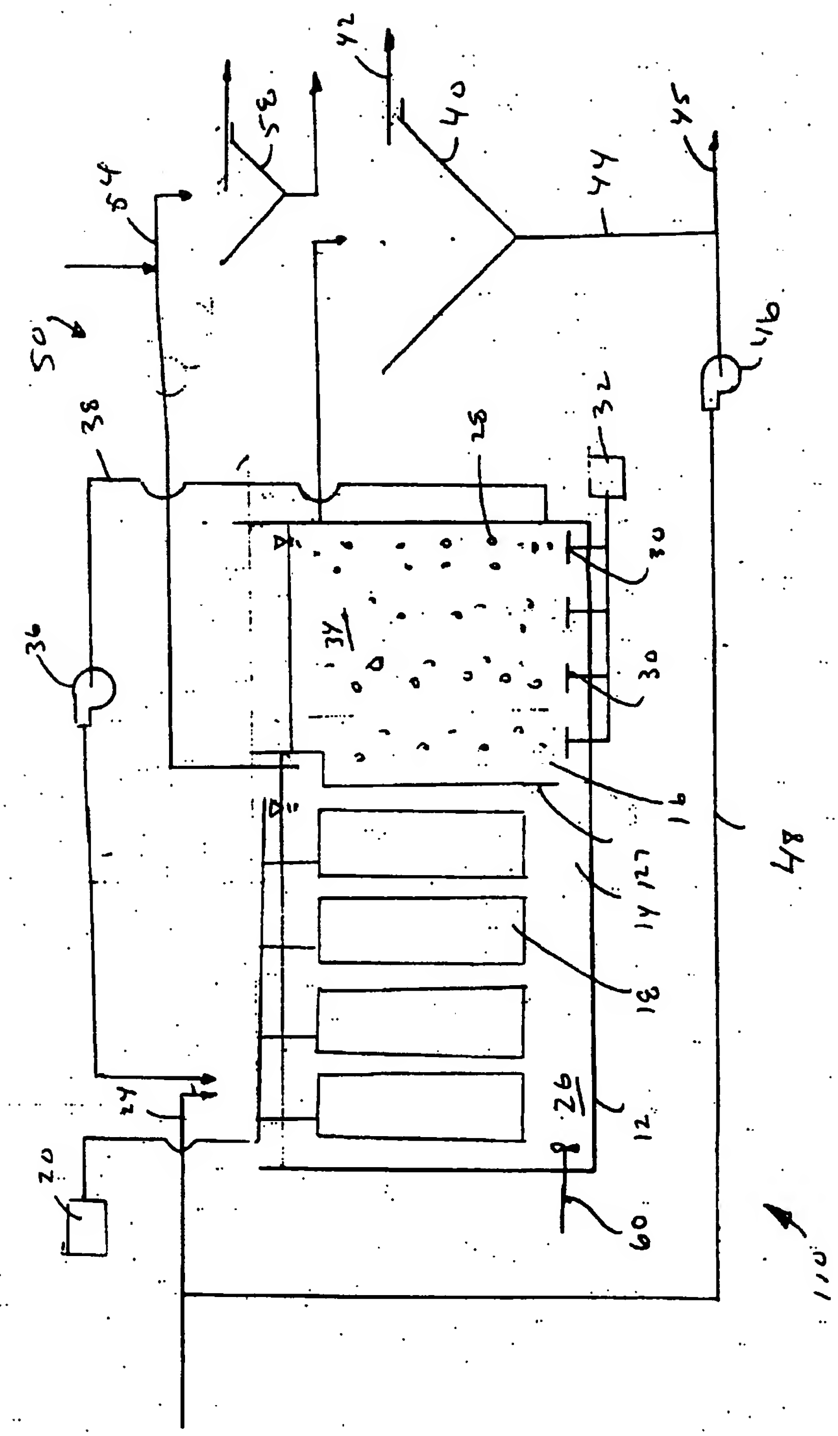


FIGURE 2